AOARD REPORT

Trip Report - Structural Materials Research at Defense Metallurgical Research Laboratory and the Indian Institute of Science

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This report summarizes the first orientation visit of AOARD to India, and gives the highlights of discussions regarding cooperative research and development opportunities at the Defense Metallurgical Research Laboratory, Hyderabad, and the Indian Institute of Science, Banglore. Both institutions welcomed the opportunity for more cooperative programs between the US Air Force and Indian institutions of basic science. Details regarding AOARD programs were given, and several proposals for research and other AOARD support were discussed.

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US Embassy, Delhi

During my brief visit to the US Embassy in Delhi, I was able to meet with staff from the Defense Assistance Office (DAO), the Science Counselors Office, and the Defense Supply Advisors (DSA) office. Discussions with all three groups centered around introducing AOARD and its mission to the embassy staff, and to learn more about the US India Aid Program. Everyone was very supportive of our mission and encouraged us to be active players in India.

The DAO in India is composed of the military attaché offices of the three services. DAO's primary interest seemed to be politics and intelligence gathering, and they are generally not involved in science, technology or foreign military sales (FMS). I met with Col Richard L. Davis, the Air Attaché, and Capt Ron A. Dionne, the Assistant Air Attaché. I briefly informed them of the AOARD mission in Asia. Capt Dionne was very helpful in arranging the visit to the embassy, and making other arrangements in India. The week of my visit also coincided with a Tri-Service IG inspection of the embassy, so their efforts and time were especially appreciated under the circumstances.

They expressed an interest in accompanying me on future trips to Defense Metallurgical Research Laboratory (DMRL) and the Defense Research and Development Organization (DRDO) in order to gather intelligence information, but I explained to them that this would be difficult due to my sensitive position in the science community. They were especially interested in any information I could gather regarding India's missile programs. Evidently, they have not been successful in obtaining approval to visit defense and civilian R&D laboratories and centers on their own in the past. However, I did promise to send them a copy of my trip report.

I then met with Col Walter T. Eastham, Defense Supply Advisor (DSA), and Lt Col Terry R. Lee, his assistant. DSA handles all FMS in India, of which there is reportedly very little at the present time. Both expressed a high degree of interest in our programs, especially the Asia R&D thrust, and offered any future assistance we might need. From what I could gather, they would be the responsible office for any government to government agreements with India. We talked a short while about the India Fund (PL 480), and they referred me to the science counselors office for more detailed information. They also showed interest in my visit to defense laboratories, and requested a copy of my trip report.

My last visit was with the Science Counselor, Dr. Paul C. Maxwell, and his Indian national assistant, Mr. Sudarshan K. Dutt, Chief of the Physical and Material Sciences Division of the Office of Science and Technology. Dr. Maxwell explained that the US-India agreement which covers PL-480 funds expires in 1997, and the funds for the program would likely expire sometime in 1995 or 1996 if programs continued to be funded at historical rates. There are currently approximately 200 projects expending approximately $8-9 per year. Keeping in mind the dramatically lower cost of research in India (approximately 1/10th the cost of research in the US), there is a considerable amount of research taking place under the program.

He explained his interest in seeing the program continue, and that interested parties on the US and Indian side had expressed similar interest. He has worked to change the program so that a perpetual endowment could be created by more effectively managing the remaining funds. This would dictate that there would be fewer programs in the future, and that the interested organization would be encouraged to provide matching funds. In light of the low cost of Indian research, the high quality of research being done by many groups, and the opportunity to leverage AOARD research dollars with the PL 480 funds, India presents a unique and valuable opportunity for Air Force ICR&D.

Defense Metallurgical Research Laboratory, Hyderabad

My visit to DMRL coincided with the Workshop on Structural Intermetallics - Perspectives on Science and Technology, 5-6 February, which was sponsored by the Materials Research Society of India, and co-sponsored by the AOARD Conference Support Program (CSP). DMRL acted as the host of the workshop. The purpose of the workshop was to assess the current trends in the application of intermetallics for structural applications. There were a total of 22 papers presented, eight from foreign invited speakers, covering structural intermetallics. Most of the talks, in line with the theme of the workshop, focused on applications and technical challenges for structural intermetallics. The alloy systems discussed included Ni_3Al, NiAl, Ti_3Al, TiAl, Fe_3Al, Fe-Al-X, and Zr_3Al.

Most of the research in India on intermetallic compounds has focused on alpha-2 Ti_3Al-based alloys, and more recently on the orthorhombic alloys based on Ti_3Al-Nb. The orthorhombic alloys have received attention in the last several years, due in part to the inadequate oxidation resistance of the classic alpha-2 alloys. Dr. Dipankar Banerjee, an Associate Director of DMRL and Director of the Metallic Division , was the first to identify and characterize the orthorhombic phase. The work at DMRL, led by Dr. Banerjee, has been and continues to be at the forefront of the international development effort on these alloys. Valuable collaboration between USAF Materials Directorate scientists and DMRL scientists has greatly enhanced our understanding of the important Ti-Al-Nb system.

The M in DMRL is a bit of a misnomer. DMRL not only conducts research on metallurgy, but is the materials research laboratory for all of the Indian Ministry of Defense. DMRL has close ties with the US materials community, due to the fact that many of their scientists were trained at some of the best US universities.

It appears that a large amount of the research conducted in the Metallic Division, supports maintenance and upgrades to their aircraft inventory of Soviet MIG fighters. Therefore, there is some advanced development work on conventional titanium and nickel based alloys. Some of this work is in support of indigenous Indian alloys. Additional information on DMRL, a trip report of a fellow traveler, Dr. Dan Miracle of WL/MLLM, is attached.

DMRL, due at least in part to the relative immaturity of its aerospace industry, carries out the majority of defense related materials research up through advanced development, prototype and sometimes even production. Because of this, DMRL is uniquely staffed and equipped. While much of the historical work of DMRL has centered around support of existing or imported hardware, there is an increased emphasis on indigenous research, development, and production. Perhaps the most visible examples of this are India's efforts in missiles and rockets, although there are also projects underway to develop an indigenous trainer, jet engine, and a turboprop powered small transport which has both civilian and military projected uses.

The fledgling titanium industry in India is a good example of the governments attempts to encourage and promote aerospace industry in India. Although India is a world exporter of several ores used to produce titanium sponge, India has no indigenous commercial sponge making facilities. They commercially produce $TiCl_4$, a product used in the production of Ti sponge, and also have commercial facilities for melting and working Ti and Ti alloys, sponge production remains the missing step in their capability. DMRL has conducted research on sponge production for several decades, and currently operates a pilot plant,

where the size and technology appear to be world class. This technology is available for commercialization by Indian industry.

Examples of DMRL's other excellent facilities are it's 2000 ton isothermal forging press, VAR furnace, state-of-the-art materials characterization facility, pioneering electro-chemical slag remelting facility, among others. DMRL also has close ties to India's premier technical university, the Indian Institute of Science (the MIT of India) and the civilian National Aerospace Laboratory, which are both in Banglore, and the National Metallurgical Laboratory in Jamshedpur.

Indian Institute of Science, Bangalore

The Indian Institute of Science, or IIS, is the largest and most prestigious science and technical university in India. In the Department of Metallurgy, I met with Professors Kamanio Chattopadhyay and Professor Y.V.R.K. Prasad. Prof Chattopadhyay's research interests include processing/ microstructure relationships in intermetallic compounds, processing and characterization of quasicrystals and issues with metal/ceramic interfaces. His latest research thrust is on nanocomposites, where soft reinforcements are introduced as a hyperfine reinforcements in a hard matrix.

Professor Prasad, currently the acting department head, is well known for his work in modeling deformation processing and processing maps. He spent several years at the AF Materials Laboratory at Wright-Patterson AFB working with the processing science group. His laboratory includes a custom designed deformation simulator, which has been used to generate data used in the formation of deformation maps for dozens of Ti, Al, and Ni alloys.

I then met with Professors A.V. Krishna Murty and R. Narashima of the Department of Aerospace Engineering. The department just celebrated their 50th year anniversary last year, and I received several brochures and pamphlets which outline the size, scope, and areas of research in which the Department is involved. This information is also available, upon request. The Aeronautical Engineering is the largest department at IIS, with 33 professors, and approximately 122 graduate students. The majority of the graduates go to work for one of the several military or civilian government laboratories, or HAL, the largest Indian aerospace company. The majority of funding for research projects also come from the same organizations, and the Aeronautical R&D Board, a inter-governmental funding oversight organization.

Professor Murty, the current director of the department, is seeking collaboration with Dr. Venkayya of the Flight Dynamics Directorate of the Air Force Wright Laboratory (WL/FIBRA) in the area of structural dynamics. We discussed plans for AOARD to fund Dr. Murty's visit to WL in May under the WOS program. Professor Narashima is the former director of India's National Aeronautical Laboratory, from which he recently resigned or retired. While at NAL last year, AOARD also funded his visit to a AFOSR sponsored workshop on CFD under the WOS program. We discussed possible support for a workshop which he is organizing.

Facilities at the department include two low speed wind tunnels, 4.3m x 2.7m and 2.2m x 1.5m, a hypersonic wind tunnel, a shock tunnel, a flutter tunnel, and various material and structural production and testing equipment.

Summary

Although I was only able to visit and assess several groups at DMRL and IIS, overall I was very impressed with the quality of research, the research equipment, and the research staff at both organizations. In light of the low cost of research in India, the high quality of research being done by many groups, and the opportunity to leverage AOARD research dollars with the PL 480 funds, India presents a unique and valuable opportunity for Air Force ICR&D. Additional information regarding commercial and governmental aerospace and materials organizations is available upon request, in the form of several articles and brochures.